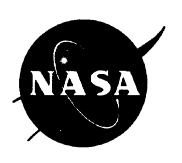
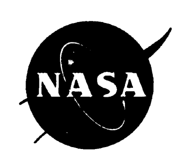




Lunar Reconnaissance Orbiter FlatSat

Michael Wright
NASA Goddard Space Flight Center
Flight Systems Integration & Test

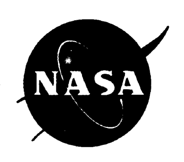




FlatSat Purpose

- Allows early ITOS proc & procedure development for I&T and flight ops
  - Development of functional/interface tests, CPT, and other system-level tests
  - Procedure validation
- Preliminary hardware/software verifications can be performed with ETU's
- Platform for system-level testing of flight software
- Platform for troubleshooting during flight I&T
- Testbed for personnel training (engineers, test conductors, technicians)
- Post-launch flight ops support (following delivery to MOC after launch)

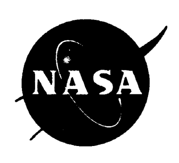
Flatsat provides substantial risk reduction for I&T, and for flight operations





Facility Requirements

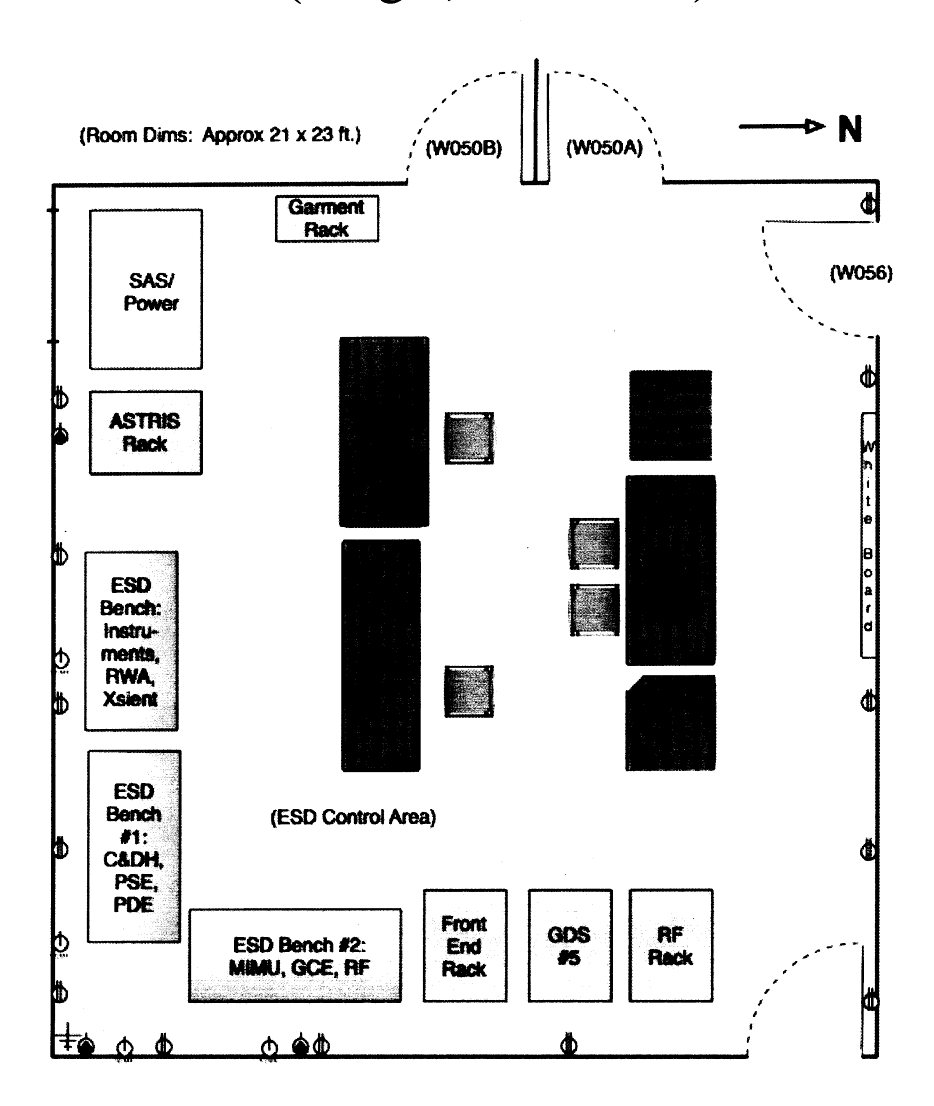
- ESD Control
  - Room modifications (e.g., floor stripping)
  - Certified ESD benches and equipment
  - Personnel certifications (IAW NASA-STD-8739.7)
- Cleanliness
  - Lab: Standard cleanliness
    - General cleanliness implemented IAW LRO Contamination Control Plan
    - Weekly cleaning and garment change-out by CC personnel
    - Periodic monitoring by QA to ensure cleanliness is maintained
  - Bench: Visibly clean
    - Periodic cleaning by CC personnel, as required
- Power
  - Facility 110/208, with UPS backup
  - Outlets and ground plate added to existing room

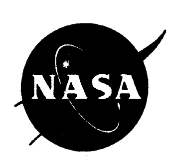


LRO FlatSat Lab

(Bldg 5, Rm W050)



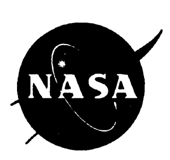






Flatsat Component Diagram

GSE
GDS
ETU HdW
Sim Flt HdW
Pwr
SpW
Signals
I&T Network
1553
1PPS
RF Modulated Data
RF Hdw
HGA
Ka-Xpndr
ACS Components
Star Tracker
Reaction Wheel
S-Band Front End Processing Rack
Ka-Band Front End Processing Rack
PDE ETU
GDS Rack #b
HGA Deployment System
SA Deployment System
Propulsion System
Simulated ACS Component Pwr Loads
MAC heater loads
Star Tracker X 2
RWA X 4
SA Gimbal Cntlr
HGA GCE
CSS (x 8)
Simulated 1553 Bus Instrument Interface
GDS
TLM Data & Clock
C&DH ETU
Comm Card
SBC
DIB
HKIO
MAC
LVPC
Data Storage
1PPS
28 VDC
1553
SpW sim
LROC
MINI RF
LAMP
SpW
Serial IF
MAC Analog Inputs
Cmd & Clk Data
LOLA
CRaTER
LEND
DLRE
Chan Data
PSE ETU
Thermistors (x 171)
Sep Signals
ITOS Workstation
Data Archive
1553 Bus Monitor
Battery Simulator Rack
Solar Array Simulator Rack
UPS
Chart Recorder
I&T Network





FlatSat Functional Configuration

FLATSAT Table

Transient Componets
Spacecraft Instrument ETU's

ACS Components
Gyro
Starr Tracker
Reaction Wheel

S-Band Proto-Flight
Transponder

Ka-Band Simulator ETU

PSE
J24 DPC Umbilical Power
J23 Solar Array Simulator Power
J25, J26 Battery Power

Output Modules

PDE
J510 Separation Brealwire 1
J511 Separation Brealwire 2
J520 PDE IU Relay

PDE A, B, C, & D
J[1|2|3|4]50 Dual Switch Interface
J[1|2|3|4]60 Single Switch Interface
J[1|2|3|4]70 Telemetry Interface
J[1|2|3|4]80 GSE Interface

C&DH
Ka-COMM
Gore/Spinner 4 Port Twinaxial
J53 TLM Data
J54 GSE TLM Data

S-COMM
J44 XPNDR A Interface
J43 XPNDR B Interface
J38 GSE TLM Interface
J37 EELV TLM Interface

MAC
J25 Analog Input Port 1
J26 Analog Input Port 2
J20 Analog Input Port 3
J21 Analog Input Port 4
J42 Heater Power

HK I/O
J30 LAMP Interface
J35 1PPS Interface

Transient GSE
Instrument GSE

Time Testing Equipment

RF Ka-Band Rack

RF S-Band Rack

Separation Signals

Umbilical DPC Power

Solar Array Power

Battery Simulation

Load Simulation

ACS
Component
Loads

PGSE Double Rack
Solar Array Simulator

Battery Simulator

Load Simulator

E-NET Boxs

LVDS High Rate I & Q Channel Data

Command Clock & Data

Telemetry Data
2 Mbps Max
4 Sources Available

LAMP Instrument Simulation

MAC
Analog Inputs

1 PPS

Instrument Simulation

GDS #5
Simulated ACS
Component Power Loads

Simulated ACS Components
4 Reaction Wheels
2 Star Trackers
10 Coarse Sun Sensors
4 Prop Pressure Trancducers
5 MAC Heaters (Loads)
MAC Thermisters, PRT's
Gimbal Control (HAG & SA)

PDE Interface
4 80 Newton Thrusters (NT)
8 20 Newton Thrusters (AT)
1 High Pressure Latch Valve
6 Low Pressure Latch Valves

Deployables
2 Pyro Valves
4 NEA's for Solar Arrays w / 2 initiators
2 HGA w/ 2 initiators

Simulated 1553 Bus
Instrument Interfaces

Umbilical / Front End Rack
DPC Power Supply

Separation Signal Switches

LAMP
Simulator Box

Space Wire Test Set

10/100/1000 Ethernet Switch

PRL
LVDS / ECL
Converter Box

I & Q Clock & Data

IN-SNEC
(High Data Rate Reciever)

ITOS
(High Data Rate Server)

ITOS Primary Workstation
GPS Card
(Clock Correlation)

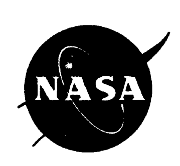
PCI Cda
(CMD & TLM Interace)

Bit Sync
(PCI Card with External Unit as Backup)

TLM
(CLK & Data)

ITOS Workstation

Printer





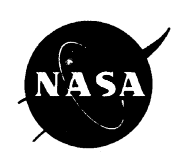
FlatSat Plate Layout (Typical)





Operational Documentation

- Released drawings for Flatsat components
- Approved WOA's and procedures
- ITOS scripts and procedures
- Logbooks
  - Test conductor logbook
  - Mate/demate logbook
- As-run archives
- Problem reporting
  - Problem records for minor anomalies
  - Problem/Failure Reports (P/FR's) for major problems
- Configuration Change Requests/Notices
  - For changes to delivered hardware/software
  - For changes to Flatsat system

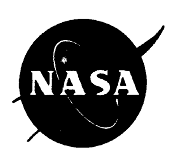




Facility Scheduling



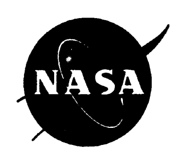
- FlatSat schedule based on initial inputs from deliverable providers
- Use of facility for use of lab prescheduled through Lab Manager
  - Use of online scheduling system
  - For subsystem, instrument, and system-level testing
  - For GSE and facility work
- Changes to schedule tracked on a daily basis
- Schedule coordinated with project schedule, I&T manager, and systems engineering





Typical FlatSat I&T Schedule

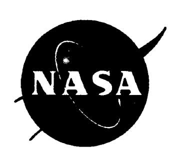
Activity ID	Activity Name	Duration (Work Days)	Start Date	Finish Date
42	FSW System Test Practice w/ Build 2.0	64.00	6/4/07	[illegible]
25	LPC Simulator Setup at Flatsat Bench	1.00	[illegible]	[illegible]
44	PSE Functional Test	2.00	[illegible]	[illegible]
32	LPC Simulator E-Integration, STM	1.00	[illegible]	[illegible]
31	LPC Simulator Interface Testing	2.00	[illegible]	[illegible]
61	(Rec) USO-8800 Protoflight (no new case)	0.00	[illegible]	[illegible]
67	USO-8800 Mount to Flatsat Plate	0.50	[illegible]	[illegible]
68	USO-8800 E-Integration, STM	1.00	[illegible]	[illegible]
45	CAD&H Functional Test	2.00	[illegible]	[illegible]
33	LPC Simulator Deintegration	0.50	[illegible]	[illegible]
62	ASTR-EU Funct & System Testing	11.00	[illegible]	[illegible]
22	CAD&H Proc Verification with USO-8800	1.00	[illegible]	[illegible]
71	USO Deintegration (Return to CAD&H Lab)	0.50	[illegible]	[illegible]
8	Ka-Modulator Simulator Testing	2.00	[illegible]	[illegible]
101	FSW Testers (Post Ka Mod Simulator Test)	0.50	[illegible]	[illegible]
47	(Rec) RWA ETU	0.00	[illegible]	[illegible]
48	RWA ETU E-Integration, STM	0.50	[illegible]	[illegible]
49	RWA ETU Functional Test	0.50	[illegible]	[illegible]
1	LLMC ETU Setup at Flatsat	0.00	[illegible]	[illegible]
50	RWA Proc Development (as req'd)	5.00	[illegible]	[illegible]
64	LLMC ETU E-Integration, STM	2.00	[illegible]	[illegible]
65	LLMC ETU Functional & System Test	2.00	[illegible]	[illegible]
40	Data Flow Test w/ VOC	2.00	[illegible]	[illegible]
57	(Rec) C&DH EDU	0.00	[illegible]	[illegible]
58	C&DH EDU Mount to Flatsat Plate	2.00	[illegible]	[illegible]
43	Closed-Loop Test w/ [illegible]	2.00	[illegible]	[illegible]
26	(Rec) PSE Surrogate (PSE-S)	0.00	[illegible]	[illegible]
27	PSE ETU Deintegration, Mount PSE-S	1.00	[illegible]	[illegible]
55	C&DH EDU E-Integration, STM	5.00	[illegible]	[illegible]
29	PSE-S E-Integration, STM	5.00	[illegible]	[illegible]
14	(Rec) LOLA Simulator	0.00	[illegible]	[illegible]
2	LOLA Simulator Setup	1.00	[illegible]	[illegible]
4	LOLA Simulator E-Integration, STM	2.00	[illegible]	[illegible]
91	C&DH EDU Functional & System Testing	5.00	[illegible]	[illegible]
12	LOLA Simulator Functional & System Test	5.00	[illegible]	[illegible]
8	C&DH EDU Deintegration	0.50	[illegible]	[illegible]
63	ASTR-EU Deintegration	0.50	[illegible]	[illegible]
123	(Rec) S-Band TT&C Protoflight Unit	0.00	[illegible]	[illegible]
124	S-Band TT&C Protoflight Mount to Plate	2.00	[illegible]	[illegible]
113	(Rec) Flight Software Build 4.0	0.00	[illegible]	[illegible]
114	FSW Build 4.0 Installation	0.50	[illegible]	[illegible]
125	S-Band TT&C E-Integration, STM	2.00	[illegible]	[illegible]
116	Rerun Procs w/ Build 4.0	30.00	[illegible]	[illegible]
126	S-Band TT&C Functional & System Testing	5.00	[illegible]	[illegible]
127	S-Band TT&C ProtoFlt Deintegration (to [illegible])	0.50	[illegible]	[illegible]
32	(Rec) PSE ETU back from Flight I&T	0.00	[illegible]	[illegible]





Deliverables

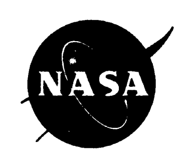
- Furniture: workstations, lab benches, cabinets
- Harness
- Mounting plates
- GSE: Solar Array Sim., Goddard Dynamic Sim., C&DH
- ITOS (ground station) workstations
- Scripts and displays
- I&T procedures
- Subsystem ETU's: C&DH, PSE, PDE, Gyro, ST, RWA, RF
- Flight Software w/ C&T database
- Instrument ETU's & Simulators
- Transient GSE: ACS, RF, timing, instruments





Flatsat Cost Mitigating Factors

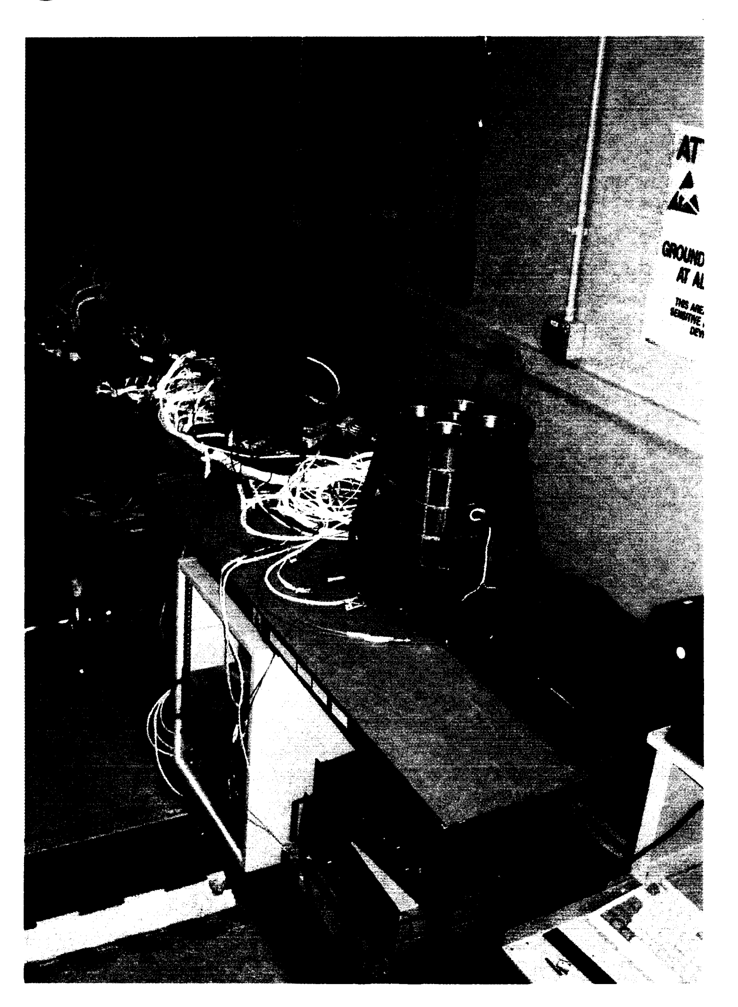
- Facility
  - Temporary, so space and comfort not as critical
  - Flatsat system planned for relocation to Mission Ops Control Center
- ETU's and Simulators
  - Designed to support only one mission (i.e., not like HST or STS)
  - ETU "loaners" only required for short-term (from vendors, other projects)
- GSE
  - Some required anyway for flight I&T and as spares (e.g., RF GSE)
  - Some used for multiple-project support (e.g., DVM's, scopes)
  - Some acquired from previous projects (UPS, racks, tools)
- Furniture
  - Not required for long-term use
  - Most obtained from excess (desks, chairs, shelves, conference table)

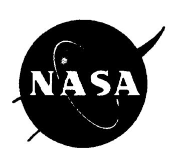




Current Configuration









Issues & Lesson Learned

- Institutional support and available facilities were limited for LRO Flatsat
  - Due to limited budget and allocations previously assigned to other high-priority projects.
  - More intra-center support and earlier communication regarding facility and support requirements is recommended.
- Some Flatsat I&T occurred in parallel with subsystem development and flight I&T
  - Projects in general should plan & arrange for more robust support to parallel operations.
- Flatsat ETU's and GSE were occassionally deintegrated from Flatsat for use in development labs
  - Although unanticipated troubleshooting may require high-fidelity units, the impacts of removing elements from the system testbed environment must be fully assessed by systems engineering.
  - However, having multiple ETU's to support in parallel both subsystem development and Flatsat system-level testing was an advantage.
- Concurrent requests for lab use and delays in ETU deliveries resulted in lab scheduling challenges
  - Having a centralized scheduling system, and resident lab manager for real-time rescheduling, facilitated effective lab utilization.